AKERMIN

Putting enzymes to work™

ENZYME CATALYZED PROCESS FOR LOW COST CO_2 SEPARATION AND CAPTURE

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AGENDA

- Introduction
- Akermin Technology
  - Enzymes
  - Benefits
  - Results of Economic Modeling
  - Laboratory Test Results
- DOE Pilot Project
- Conclusions

AKERMIN, INC.

- St. Louis-based biotechnology company
- Developing next generation cost and energy efficient, environmentally benign systems for CO_2 capture
- 22 FTEs; seven Ph.Ds
- Funded by VCs and strategic investors
- Combining biochemistry, nanotechnology and engineering to develop and commercialize a novel, low-cost solution for carbon management

BIO RESEARCH & DEVELOPMENT GROWTH
BRDGPark
AT THE DANFORTH PLANT SCIENCE CENTER

THE CHALLENGE

CO_2 Management Today

Driving the Need is Growth in:

- Process industries requiring CO_2 capture
- Supply/demand for natural gas
- Demand for EOR
- CO_2 emissions
- Carbon capture regulations
- CO_2 feedstock for mineralization and bio-utilization

- Expensive, need dramatic cost reductions
- Political and regulatory uncertainties
- Revenue plays hampered by costs
- Dominant solution: Amine solvents
  - Reliable, yet expensive
  - Environmentally undesirable & require special handling
  - Issues with degradation and corrosion
  - High investment cost and energy consumption
- Delay in large-scale adoption

Growth, uncertainty and cost create CO_2 management opportunities

OUR FOCUS

'Bridging the gap' to provide a biocatalyst-enabled industrial solution

Biocatalysts

- Nature's perfect solution, Carbonic Anhydrase
- Over 100 times faster than best amines
- Short life in industrial process

Akermin's Solution: Putting Enzymes to Work

- Solves problem of economic delivery of biocatalyst
- Protects biocatalyst using unique, proprietary polymer films
- Combines biochemistry and nanotechnology with engineering
- Capital-light using partnership model
- Scalable
- Compatible for new and existing systems
- Simple and environmentally-friendly approach

Customer Needs

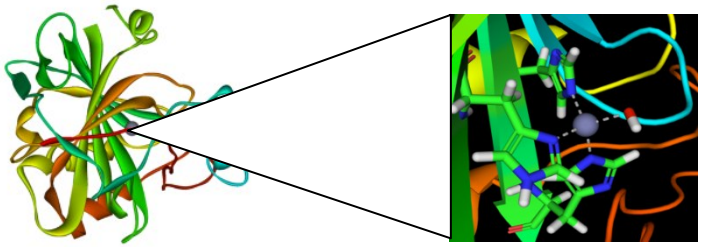
- Continuous processes
- Robust solutions
- Reduced capital intensity
- Simplified process
- Flexible/adaptable
- Low lifecycle cost

Disruptive Solution for CO_2 Management

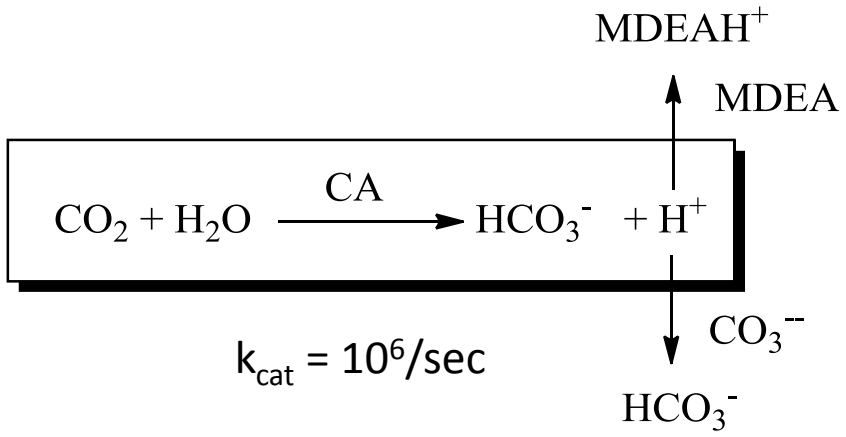
OUR SOLUTION

Biocatalyst Delivery System

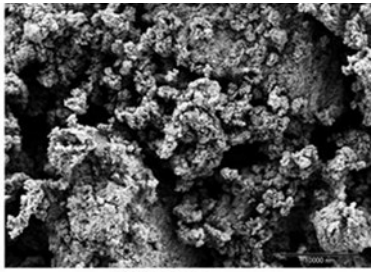
Carbonic Anhydrase (CA)



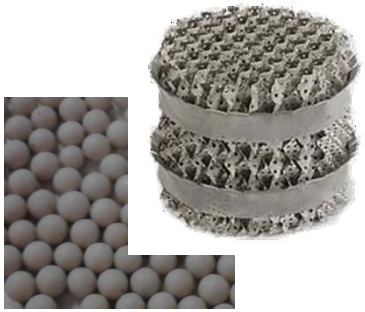
Active site



CA is integrated in polymer with high surface area to minimize diffusional limitations



5kV 2500x mag

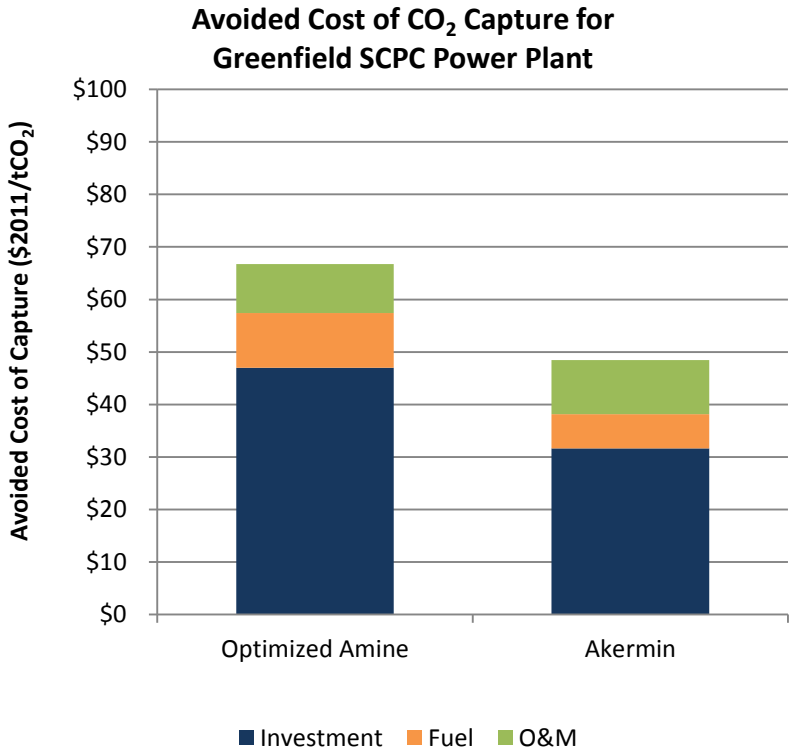


- **Uses nature's best tool, CA, to accelerate CO_2 absorption**
- **Integrates biocatalyst into scalable low-cost proprietary polymer film**
  - **Maximizes performance**
  - **Extends biocatalyst lifetime**
- **Works with conventional mass-transfer devices**
  - **Reduces scale-up risk**

KEY BENEFITS

Total cost of capture over 30% less than optimized amine systems

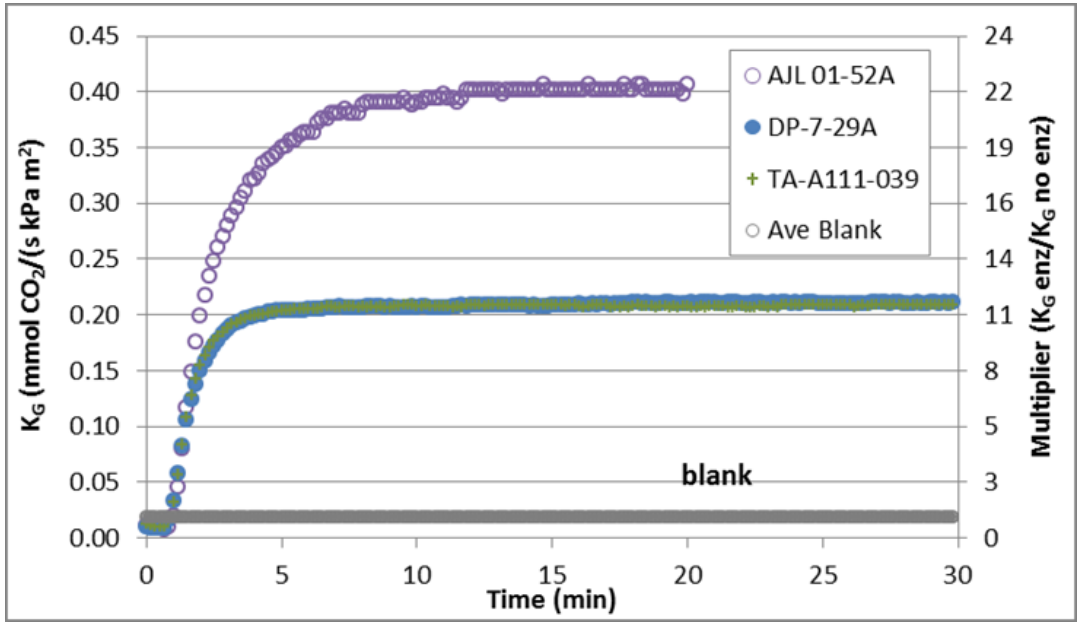
- Reduced capital costs
  - No polishing FGD
  - No wash columns
  - Minimal/no intercooling
  - No reforming
  - Reduced requirements for solution handling & storage
- Reduced operating costs
  - Lower costs for solution replacement
  - Lower cooling requirements; water consumption
  - Energy-efficient process; development target of 2.5 GJ/t-CO_2
- Environmentally-friendly
  - No solvent emissions to the atmosphere
  - Produces **benign by-products** with low disposal costs, opportunities for **resale**

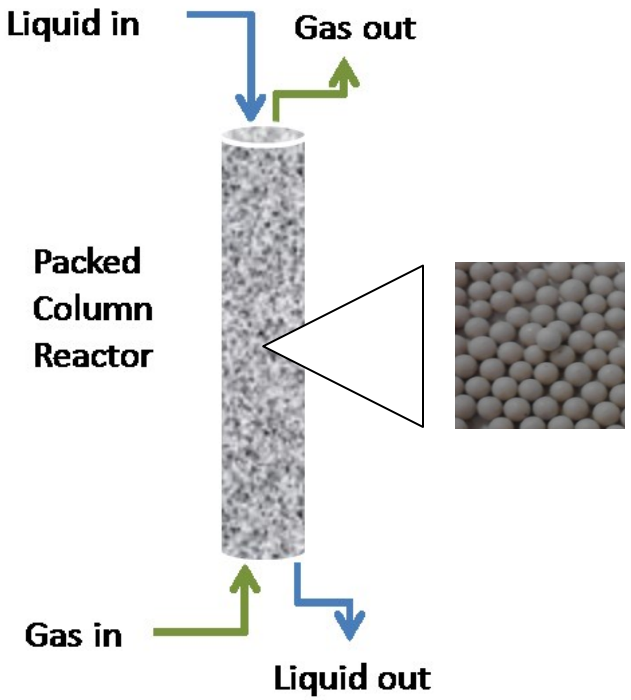


Enables a simple process chemistry and design that yields a low-cost solution for CO_2 capture

PERFORMANCE OF BIOCATALYST IN A COUNTER-CURRENT FLOW COLUMN

20% Lean CO_2 loading at room temperature
p = 1 psig



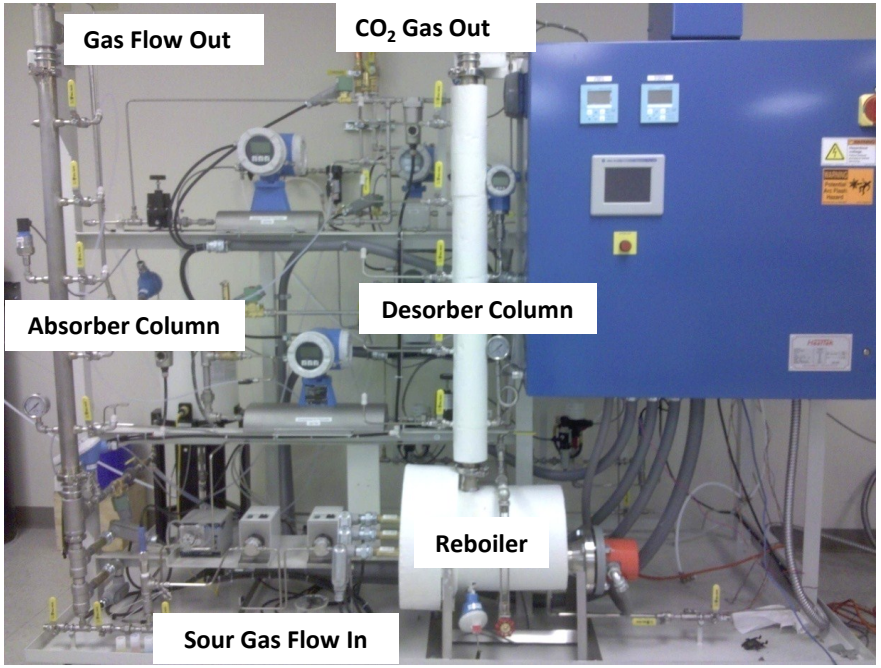


Note: K_G reported per packing area, lab-scale test reactor interfacial area ~ 30%

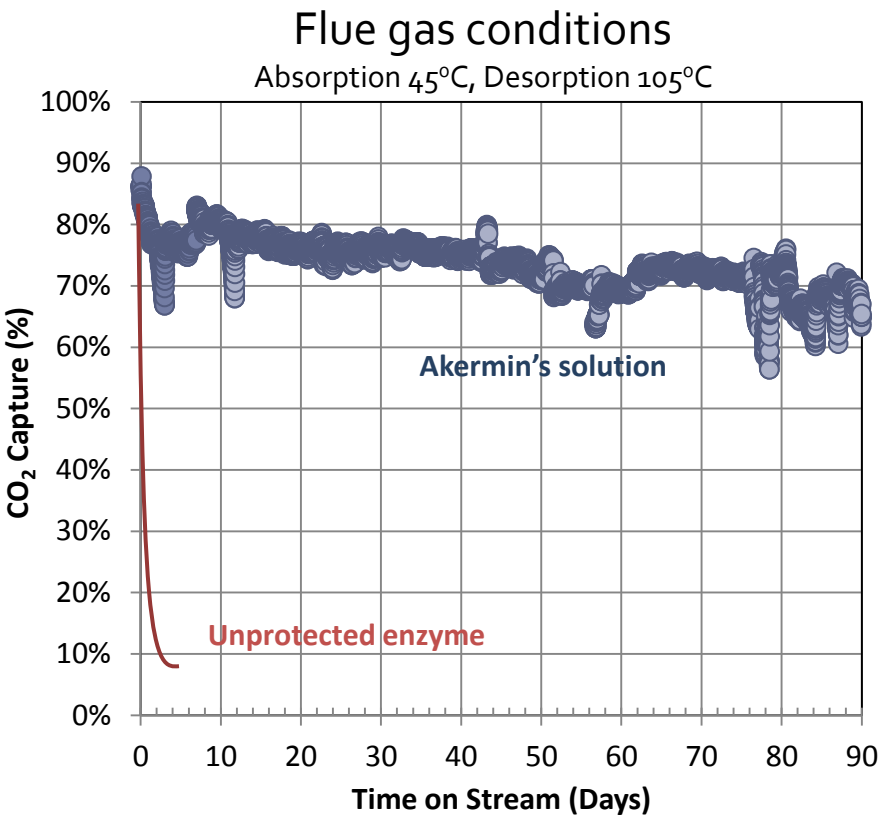
Up to 22-fold increase of K_G was demonstrated

LONG-TERM PERFORMANCE

Confirmed commercially-viable performance levels

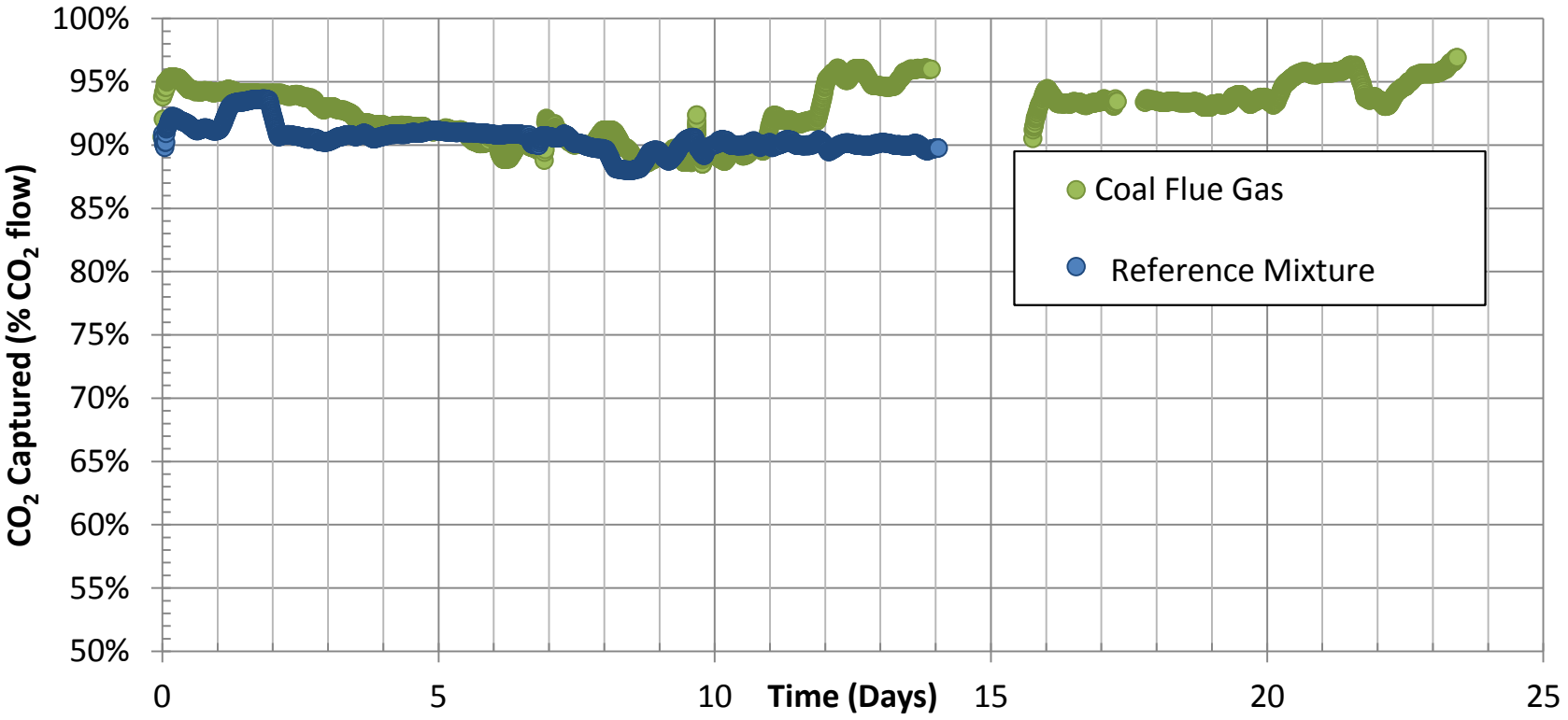


Akermin's Closed Loop Reactor



Over 20 million CO_2 molecules hydrated by one CA molecule over 90 days
Translates into > 400 kg CO_2 captured per day per kg of CA

TESTING ON FLUE GAS



Flue gas generated from Wyoming Powder River Basin subbituminous coal
Total mercury content (Hg^{2+} and Hg^{0}) ~ 2ppbw

~ 90-95% CO_2 capture sustained for over 23 days on flue gas (~14% feed)
Overall performance is stable and comparable with reference

DOE PILOT PROJECT

Demonstrate Biocatalyst delivery system on power plant flue gas

- **Project participants**

AKERMIN

Pacific Northwest NATIONAL LABORATORY

Battelle *The Business of Innovation*

- **Project duration: 33 months (initiated in October 2010)**
- **Funding**
  - Total Project: $ 4,750,000
  - DOE Funding: $ 2,910,000
  - Akermin Cost share: $ 1,840,000

200x scale-up from bench-scale, closed loop reactor

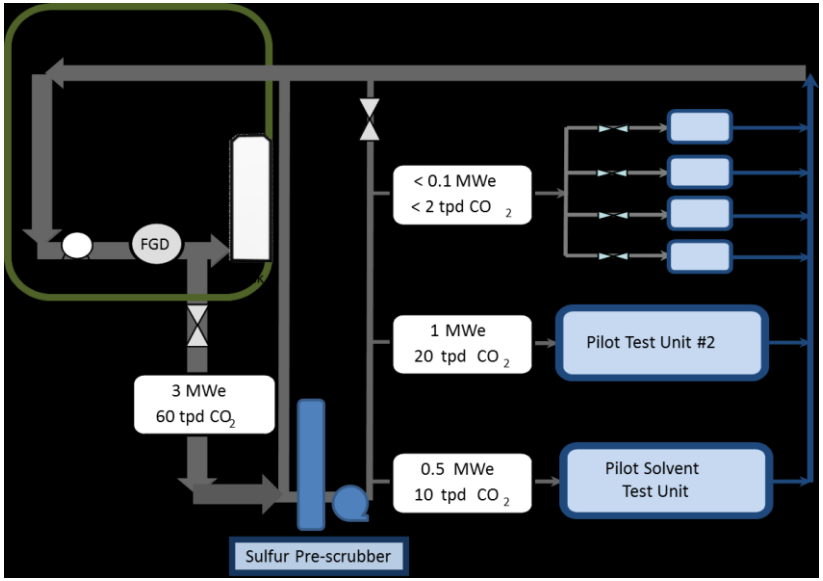
TESTING AT THE NATIONAL CARBON CAPTURE CENTER (NCCC)

Post-Combustion CO_2 Capture Center (PC_4) part of the National Carbon Capture Center (NCCC).

Located adjacent to Alabama Power's Plant Gaston.

Established in 2009 through transition of Power Systems Development Facility and supported through funding from the US DOE.

PC_4 commissioned in March 2011.



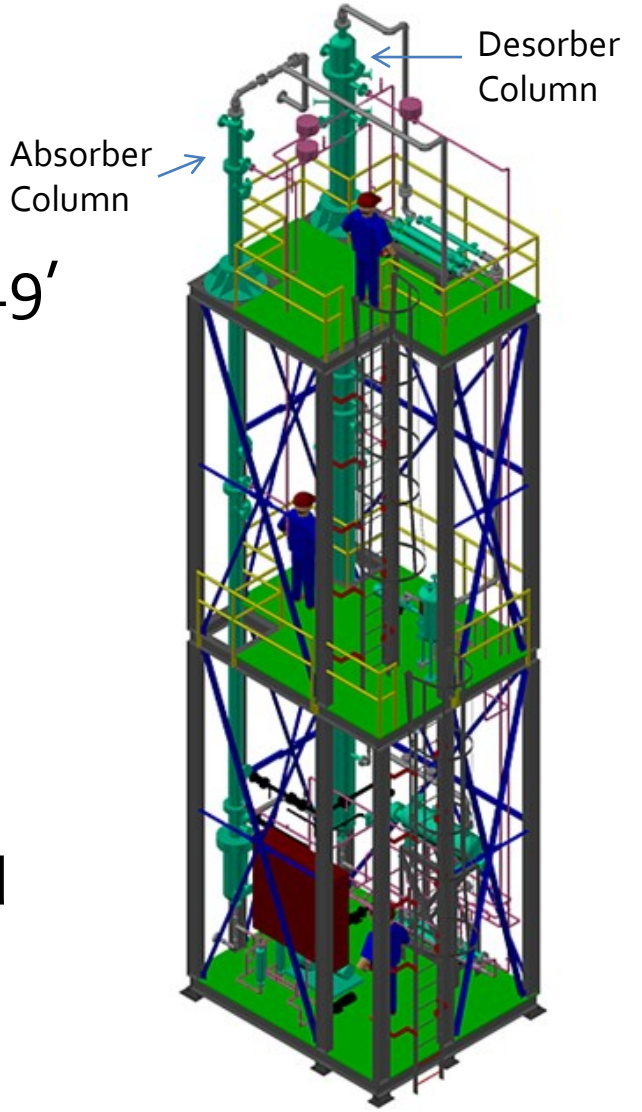
Flue gas drawn from downstream of FGD and returned upstream so any contaminants introduced are removed by FGD before passing to stack.

Akermin scheduled to commission pilot plant in 4th quarter of 2012; testing for up to six months.

KEY PROJECT OBJECTIVES – PHASE II

- **Engineer Bench-Scale Carbon Capture System**
  - 500 SLPM (5 to 10 kWe)
- **Capture CO_2 from flue gas slip-stream for up to six months:**
  - Demonstrate 90% CO_2 capture in presence of biocatalyst and potassium carbonate
  - Demonstrate long-term activity of biocatalyst delivery system
  - Characterize rate enhancement of biocatalyst delivery system
  - Demonstrate tolerance to flue gas impurities
  - Evaluate impact of external conditions on process performance
- **Generate data to refine simulation models and confirm key advantages**
- **Model capital and operating costs for commercial-scale system**

BENCH UNIT SPECIFICATIONS



- **Overall dimensions (L x W x H): 10′ X 12′ X 49′**
- **Absorber Design Case**
  - 500 SLPM flue gas (nominal)
  - Sulzer 500 m^2/m^3 packing
  - Nominal Liquid: 300 kg/hr
  - 20 wt% K_2CO_3
- **Heat recuperative cross exchanger and trim coolers**
- **Emerson Delta-V Control System**

UPCOMING ACTIVITIES

Fabrication of Bench Unit	June – October 2012
Scale-up coating process and coat contactor	November 2012
Install/Commission	November 2012
Initial Testing (blank)	December 2012
Initial Testing (biocatalyst)	January 2013
Operate unit for six months	January – June 2013
Model and evaluate the capital operational costs for full-scale coal-fired power plant	June 2013

PROJECT TEAM

AKERMIN:
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John Reardon, PI; Director, Engineering
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Dr. Matt Hulvey, Senior Scientist
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ANY QUESTIONS?

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